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By DAVID FRASER HARRIS, M. D., B. Sc. (Lond.), D. Sc., F. R. S. E., F. R. Sc.,

PROFESSOR OF PHYSIOLOGY AND HISTOLOGY, DALHOUSIE UNIVERSITY,
HALIFAX, N. S.

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THERE were two great workers with the microscope in the latter half of the seventeenth century—the Italian, Malpighi, and the Dutchman, Leeuwenhoek. Of these the former was in his own time and still is in our day by far the better known man.

Malpighi was the father of all such as work with the microscope; the creator of histology everywhere, not merely of Italian, the father of both the histologies, vegetable and animal. Much of his life was spent in Bologna, the old-world, arcaded, sun-bathed city, the seat of a university founded more than 800 years ago.

But very different was the place to which my wife and I made a pilgrimage in the Christmas holidays of 1907, the unfrequented little town of Delft in Holland, if known in more than name to the great mass of my countrymen, known as the seat of the manufacture of a certain kind of pottery called "Delf."

Though the place is by no means devoid of interest, all its other interests are for biologists thrown into the shade by the recollection that this was the scene of Leeuwenhoek's life-long labors with the microscope, the place where the first bacteriologist was born, lived, worked, died and was buried. The town is on the line of the canal between Rotterdam and the Hague. Modern it certainly is not, for it was founded at the end of the eleventh century by Duke Geoffrey of Lorraine. In the palace or Prisenhof, William of Orange was assassinated in 1584; in the old church or Oude Kerk as old as the town itself, two of Holland's naval heroes, Van Tromp and Piet Hein, lie buried.

Its New Church, founded in 1381, is the last resting place of a most important person in the history of European theology, Hugo Grotius (Groot). Here, too, is the family tomb of the Princes of Orange. In 1654 there occurred a disastrous gunpowder explosion in which upwards of 1,200 inhabitants perished.

Delft is best known for its pottery, but this industry is almost extinct, the present manufactures being carpet-weaving, distilling and dyeing; there is a polytechnic school, a school of military engineering, a school for the education of colonial civil servants, a school of design, a theater, and a lunatic asylum. The town which is built in the form of a square is rather gloomy, and its narrow streets, flanked by high houses, have stagnant little canals in the middle of them.

Such was the place at which we alighted from the Rotterdam train in the grey light of a January afternoon. Our fellow passengers stared as we left the carriage; they could understand our going on to the Hague, but what was there to detain an Englishman at Delft at that time of year?

Only interest in the history of biology could make one search out the ponderous Oude Kerk to view the tomb of a man whose very name is an unknown sound to all save a few. We knew, however, that in that ungainly old church towering over the crowded houses lay buried an indefatigable worker in Nature's invisible world, one whose greatest honor in life was, as it is the boast in the inscription on his tomb, to have been enrolled a Fellow of the Royal Society of London, or "of England," as it puts it.

The F. R. S. told Leeuwenhoek in his lifetime that he had not lived in vain. We know from the good work he did that, whether he had been made an F. R. S. or not, he belonged to the innermost circle of the scientific immortals. This F. R. S. was, perhaps, the one great event in a life devoid of incident, at any rate empty of anything like the incidents that filled Malpighi's.

Malpighi, for whom a chair was created by a Grand Duke and he a Prince of the Medici, who was invited to teach in the University of Messina, and then entreated to leave it for the chief professorship of medicine at Italy's premier University of Bologna, who was constrained to end his days in the elegant sinecure of physician to the visible head of Christendom, and who was an F. R. S. to boot—even his life has been described as devoid of incident! What, then, must be said of Leeuwenhoek's? Leeuwenhoek probably never left Holland, it is doubtful if he ever quitted Delft. That Leeuwenhoek was a person of reliable character may be incidentally gathered from his having been made curator or trustee for the widow of Jan van der Meer the painter who was born at Delft in 1632 and died in 1675.

Malpighi was a hereditary landowner, Leeuwenhoek began life as assistant or clerk to a linendraper. He worked all his days in the little town where he was born, and seemed content to know that not only his countrymen, but those generous men of science in the greatest city of the world had recognized his worth. Science had equal need of the landowner and the linendraper. According to some accounts Leeuwenhoek was a man of independent means which he had inherited from relatives who were brewers, but he seems for the greater part of his life to have held the post of beadle (bedellus) to some public body in Delft. The document describing his duties which were light and his emoluments which were lighter is still extant.

We were not long in finding the Oude Kerk, nor the venerable guide inside it. He was dressed entirely in black, and wore a black skull cap. He immediately directed us to the tomb of van Tromp; of course, that was what the Englishman had come to see at such a time of year. Casting a passing glance at the elaborate marble sculptures on the gilded monument of the hero, I pushed on saying, "Any light is good enough to see van Tromp's tomb by, let me see Leeuwenhoek's before the dark." To the latter, accordingly, the reverend guide led us, correcting as we went along my pronunciation of the name. At last, then, we stood before the only monument besides his discoveries that keeps the name of the great Dutchman alive on earth; and it was erected, we found, by "his sorrowing daughter," not by any admiring strangers whatsoever. As a monument it is plain and even severe; while its setting in that huge, cold, white-washed, northern church is very cheerless. Not that it was exactly neglected; some hand had placed a wreath upon it not many weeks before. The long inscription is carved on a high, narrow slab of very dark stone—marble or granite—over which is placed a portrait medallion of Leeuwenhoek that thus stands out effectively; it represents the left profile under a full wig. Below the slab is an ornamental pediment of dark stone with another inscription, and above this a marble skull is placed which appears curiously out of place, but is evidently the result of the gruesome conventional taste in mortuary lapidary art prevailing at that time. Perched on the high slab is a marble urn surmounted by a gilded torch; on the white wall behind this a single arch or vaulting springs from two very unpleasing pilasters. From the summit of the arch a female face in white marble looks down on the tomb which is surrounded by a peculiarly ugly black iron railing. The inscription is cut in clear lettering. The sense of the Latin is: "Erected to the pious and everlasting memory of Anthony van Leeuwenhoek, member of the Royal Society of England, who, by the help of microscopes which he had himself made, scrutinized the most hidden things in Nature, and thus by assiduous study learned the secrets of the physical world. These wonders he described in his native language for the instruction and admiration of the whole world. Born at Delft, October 24, 1632, died there August 26, 1723." Another inscription states that "this monument is erected to her very dear father by his sorrowing daughter, Maria a Leeuwenhoek." Her own tomb is marked by a deeply incised stone in the pavement to the left of her father's monument. These deeply cut stones in high relief are a feature of the floors of Dutch churches; they make walking over them difficult and even hazardous to the unobservant.

In the printed account of the monuments in the church we were informed that van Leeuwenhoek's friend the Dutch poet, H. C. Poot, who, in some respects, is to be compared with the famous Scottish bard, Robert Burns, honored his memory with the following epitaph which is carved in the freestone block at the entrance to the grave: "Here lies Anthony van Leeuwenhoek, oldest member of the Royal Society of London; born in the town of Delft on 24th October, 1632, and died on the 26th of August, 1723, at the age of 90 years, 10 months, and 2 days. If, O wanderer, respect for great age and wonderful gifts is universal, then guide thy steps with reverence here, for here hoary science in Leeuwenhoek lies buried."

Once more one could not help comparing the tombs of the two great contemporary microscopists of the seventeenth century. How different their last resting places; here an air of chillness, cheerlessness and massiveness pervades the place, so different from the warmth, the color, the brightness and the tinsel of the southern church of St. Gregory.

Of course we returned to pay our respects to the great van Tromp, for we would not on any account have hurt the feelings of our grave and courteous cicerone who sold us a printed account of the tombs in his church and a faded, amateur photograph of Leeuwenhoek's monument. There being nothing else to detain us, we stepped out into the dark of the winter evening.

Here, then, within a few hundred yards of one another lie three of Holland's great men—van Tromp, Hugo Grotius and van Leeuwenhoek; a hero of Holland's naval wars, a hero in Holland's religious struggles, and a hero in the peaceful, silent conquests of science in the world of the "infinitely little." But whose work remains? What have we of van Tromp's today? We have his memory in naval history, and how it was his guns that made London quake and that turned old Albermarle down to the mouth of the Thames to reply to them; we have this gorgeous mausoleum in Delft, and we have the popular song beginning—

> Van Tromp was an admiral brave and bold,
> And he walked beside the sea.

but it would be difficult to name much else.

And what remains of Grotius, in his lifetime the world-read Arminian theologian? Under the dust of our libraries rest his treatises on Divinity, International Law, Political Liberty and Dutch History. And of Leeuwenhoek?—the whole science of bacteriology, Leeuwenhoek was the first human being to see a protozoan, a bacterium and a micrococcus, and those he first described were scraped from his own teeth. It was to the Royal Society of London that these discoveries fraught with such consequences to the science of medicine were announced. The Royal Society has been at the birth of a good deal that has moulded humanity.

The passage first announcing the discovery of bacteria is in a paper, entitled "Animals in the scurf of teeth," dated September 17, 1683, published in Vol. XIV of the Phil. Trans. (1684), in which we read: "Besides these animals there were a great quantity of streaks or threads of different lengths, but like thickness lying confusedly together, some bent and some straight. These had no motion or life in them" (evidently Leptothrix buccalis). He had just described some motile protistae which he had killed by rinsing his mouth out with vinegar.

Of course Leeuwenhoek was not what we now mean by a bacteriologist; bacteriology began with Pasteur; but scientific microscopy owes a great part of its existence to the Dutchman who ground his own lenses and left a cabinet of twenty-six of them to the Royal Society which has lost them.

Baker in his treatise on the microscope says that Leeuwenhoek's lenses were not spheres or globules, but double convex lenses, with magnifying powers ranging from 40-160 diameters.

According to Professor Stirling, the microscopes used were still of the type of "simple" microscope, high as the magnifying powers were which were reached with them. "Each consisted of a small biconvex lens placed in a socket between two plates of brass which were riveted together and pierced with a small hole opposite the lens. The object to be examined was fixed at a convenient distance and its focal distance adjusted by screws." As no eye-piece was used, the microscope was technically a "simple" microscope.

"His capital discovery was undoubtedly that of the capillary circulation of the blood first announced in 1690," says the late W. B. Carpenter in the Encyclopaedia Britannica. Now, if this means that Leeuwenhoek's discovery of the blood moving in capillaries was the chief thing he saw under the microscope, it is possibly true from a physiological, although not from a morphological, point of view. Leeuwenhoek was not, however, the first to see the flowing blood in capillaries, for in 1660 Malpighi in Bologna had seen the blood flowing in those of the frog's lung. Leeuwenhoek thus discovered the capillary circulation for himself though not for the scientific world which had been informed of it through a letter from Malpighi at Bologna to Alphonso Borelli at Pisa. However the exact date of Leeuwenhoek's seeing it for the first time is 1688, not 1690, or twenty-eight years after Malpighi's discovery.

There is before me an English translation of Leeuwenhoek's classic: "The true circulation of the blood, and also that the arteries and veins are continued blood-vessels clearly set forth, described in a letter written to the Royal Society of London by Antoni van Leeuwenhoek, member of this same Society." The letter is dated September 7, 1688; and as he says that the observations that led to it began with his finding frogs' eggs in May of that year, there is no doubt that it was between May and September, 1688, that he saw living capillaries in the tail of the tadpole, the tail of the fish (stickleback), and in the web of the frog's foot. He verified and extended Malpighi's discovery without apparently knowing anything about Malpighi's work; he does not mention him in this paper; possibly he had not seen any of his writings or even heard of him. Delft was as regards science in a backwater, and for long after 1688 scientific news did not travel very fast.

True, Delft is not far from the university town of Leyden, but it is doubtful if there was one microscope in the whole university at that time. There must have been one in the town, for a student, Ludwig Hamm, discovered spermatozoa in 1674 by the aid of one, a discovery which Leeuwenhoek also made independently of Hamm. But by 1688 the time had not come for the introduction of physical methods into the study of medicine in the class rooms of Leyden, that was left for Boerhaave, whose discourse on "The Use of the Mechanical Method in Medicine" was given at Leyden in 1703 as the inaugural address of the third year of his professorship.

Leeuwenhoek does, however, allude to his countryman, Swammerdam, whom he quotes on the morphology of tadpoles. In this passage we find that Swammerdam mentions the "incomparable Dr. Harvey's anatomical descriptions."

The late Sir Michael Foster, in his truly admirable lectures on "The History of Physiology in the 16th, 17th and 18th centuries," gives the date of Leeuwenhoek's seeing capillaries as "1668" (p. 98); the second "6" may be a misprint for an "8."

Although Delft was not a university town, and Leeuwenhoek not a university man and not in that way brought officially into contact with men of science, yet he happened to have as scientific confrère a young physician of considerable anatomical attainments, Regner de Graaf. This was no other than the discoverer of the ovarian follicles since known as "Graafian," and the author of a treatise on the pancreatic juice. In 1673, the year in which de Graaf died, he introduced Leeuwenhoek to the notice of the Royal Society to the fellowship of which he was elected in 1680. Leeuwenhoek contributed papers to its Transactions which may be seen in Numbers 94 to 380, but his first letter to the Secretary Oldenburg was as early as 1674. He also sent twenty-seven scientific letters to the French Academy.

As regards the red blood corpuscles or erythrocytes, Leeuwenhoek, although not the first to see them, was certainly the first, recognizing what he saw, to describe them correctly as circular in man and oval in the vertebrata below man. As early as 1674 he gave an account of these bodies in the Philosophical Transactions. But Jan Swammerdam (1637-1680) in 1658 had seen erythrocytes in frog's blood and correctly attributed the redness of the blood to these and not to the plasma; this observation was not published until 1738 by Boerhaave in the "Biblia Naturae," a posthumous edition of the works of Swammerdam. Malpighi in 1665 published an account of adipose tissue as he thought he saw it in the omentum. He described what he took to be fat-cells in the capillaries of the membrane, they were really erythrocytes. Thus as Swammerdam's observations were not published, and Malpighi's, although published, erroneous even if accessible to Leeuwenhoek, we may in a certain sense give Leeuwenhoek the credit of the priority of discovery in this matter.

It was, of course, by the presence of these cells in the blood that Leeuwenhoek could see that it moved. It is interesting to note that he is entirely Harveian in his conception of the circulation. He writes: "I could distinctly perceive the whole circuit of the blood in its passage to the extremities of the vessels and in its return to the heart." Quite recently there has been published a reprint of Leeuwenhoek's classical paper; it is one of several such in a work entitled "Opuscula selecta Neerlandicorum de arte medica." It has an English translation on the opposite side of each page and it is illustrated by facsimiles of the original illustrations of the blood-vessels in the tadpole and stickleback. Along with it goes what seems an excellent portrait of Leeuwenhoek representing him in a full wig seated at a table, lens in hand.

As to the circulation of the blood, of course there were unbelievers; each new thing has been doubted. Perhaps one of the most curious paragraphs of Leeuwenhoek's paper on the circulation is the last in which he enumerates for the benefit of the Royal Society three respectable men who had witnessed the capillary circulation. He says that people had remarked: "Must we believe it because Leeuwenhoek tells us?" and so he produces eye-witnesses. "But now that I hear that more credit will be given to my words when I mention the names of those who have partly seen the aforesaid circulation of the blood about which I write to your honorable Society, and which I have discovered, I have no objection to mentioning instead of many, such as I trust will deserve most belief, as, for example, Mr. Cornelius Gravesande, M. D., and ordinary professor of anatomy and surgery, and also councillor and late sheriff of this town; Mr. Cornelius Valensis, also councillor and late sheriff; Mr. Antoni Heinsius, LL. D., councillor and 'pensionaris' of this town, late Envoy Extraordinary to His Majesty the King of France, and not long ago Ambassador of this State to the Court of His Royal Majesty of England. To these gentlemen, to whom I usually communicate many of my discoveries, I have also shown the true circulation of the blood as distinctly as we see the current of the water in a running river with our naked eyes." From this we see that Leeuwenhoek entirely believed himself to be the discoverer of the capillary circulation. Perhaps the best known man who ever looked through a lens of Leeuwenhoek was the Czar, Peter the Great. He passed through Delft in 1698 and asked the man of science to visit him and bring his microscope with him. It is said that the Czar was much impressed by the spectacle of the circulation in the tail of a small eel. The East India Company from time to time supplied Leeuwenhoek with specimens.

In human histology Leeuwenhoek described the dentinal tubules, the fibers of the crystalline lens, the medulla of the hair-shaft, the epidermis, the spermatozoa, and a very great deal else; he also first discovered the striation in skeletal muscle. Leeuwenhoek was undoubtedly the first to give anything like a systematic account of the finer structure of certain insects, he described the scales on the wings, the tracheae, and the claws and appendages of spiders. He noted that the eyes of insects as well as of crustacea are facetted or compound. Besides giving a full account of the anatomy of the flea (Pulex irritans) he studied its development showing that it did not arise from sand, dust or dirt as was variously held in his day, but that it arose from an egg like every other creature he knew and passed through a metamorphosis. He remarks that "This despised creature is endowed with as great perfection in its kind as any large animal."

He observed that the pupa of the flea was attacked and fed upon by a minute parasite. Jonathan Swift having got hold of this fact made use of it in the following clever but now hackneyed lines:

The vermin only tease and pinch
Their foes superior by an inch.
So Naturalists observe, a flea
Has smaller fleas that on him prey,
And these have smaller still to bite 'em
And so proceed ad infinitum:
Thus every poet in his kind
Is bit by him that comes behind.

It was Leeuwenhoek who first gave a satisfactory account of the Aphides and the stages of their development. He showed that what had been called "ants' eggs" were the pupae of the Aphides, that the real eggs of Aphides were far smaller and underwent development into larvae. W. B. Carpenter said that Leeuwenhoek was the first to see a Foraminifer, when in the stomach of a shrimp he found what is now called Nonionina. He gave excellent figures of Balanus. He dis-

"Poetry, a Rhapsody," 1733, Vol. XIV., p. 311, Works of Swift, Scott's Edition.

covered Rotifers and gave an account of their surviving desiccation, a condition now known as latent life.

Leeuwenhoek by no means neglected vegetable histology, for he investigated the structure of oak, elm, beech, willow, and fir, noting the "pitting" in conifers and giving an account of medullary rays. He has left accurate descriptions of the embryo in germination and its relation to the cotyledons. He also dealt with the general anatomy of fruits and seeds; he was the first to discover pitted vasa in secondary wood, and the first also to see crystals in plant tissues in the rhizome of the Iris.

The Franklands, in their Life of Pasteur, state that Leeuwenhoek in 1675 discovered yeast-cells in the deposit under a fermenting liquid. He wrote on the forms of crystals, of sugar in particular, on the microscopic appearance of the edge of razors, and he left directions as to how to hone them for shaving.

One feature in Leeuwenhoek's work which does not seem to be as widely known as it ought to be is his battle against the all-prevailing superstitions of his time regarding "spontaneous generation" or Abiogenesis.

It is difficult for us at the present day to realize the depth of darkness and confusion amid which men's minds worked in the seventeenth century with regard to the subject of generation. The Cochineal insect was supposed to be "the fruit of some tree," the putrefaction of the carcase was supposed to engender maggots, the putrefaction of meat to give rise to flies, insects found within galls were supposed to have arisen from the tissues of the tree, even the otherwise enlightened Redi thought this, the flea was believed to be bred of "corruption" in dust or sand, etc., marine molluscs were imagined to be produced from marine mud, and eels were supposed not only by the vulgar but also by learned men to be produced from dew or in a manner wholly inexplicable.

Leeuwenhoek was in no doubt whatever as to these things being prodigious absurdities bred of a priori zoology and Aristotle. "For my part," he says, "I hold it equally impossible for a small shell-fish to be produced without generation as for a whale to have its origin in the mud." He had risen in a manner that a great many people at the present day have not risen, to a grasp of the principle that size has nothing at all to do with the essence of phenomena; that the antecedent of a living thing is a living thing and not non-living matter or dead matter however putrid it may be.

He demonstrated to his daughter and to his engraver the embryo of Unio, the fresh-water mussel. They "watched it for three whole hours." He was particularly delighted with his discovery of the embryo eels in the body of the female, for he had been challenged specifically to show how eels were bred.

The superstitions about spontaneous generation died very hard. Well on into the eighteenth century we have Father Needham (1748), introducing sterilization, and later Spallanzani (1776) bringing fresh proofs against Abiogenesis. Cagnard dela Tour (1837), Schwann (1839) and Helmholtz worked successfully at the same problems. But the coffin of this dead heresy was rapidly approaching completion; Leeuwenhoek had found the wood, the others had put it together, while it was reserved for Pasteur and Tyndall in our own day to hammer in the last two nails with triumphant blows.

In the case of "weevils" of granaries, he showed that they were not produced by wheat, but were grubs from insects' eggs. He suggested that the granaries should from time to time be fumigated with sulphur to destroy the insects before they laid their eggs. This is quite in the modern spirit, he wished to use some sort of chemical to destroy life. In other words, he is not the mere histologist magnifying "the difficulty, looking it full in the face and passing on," but he is a physiologist as well trying to solve it.

He knew that the atmospheric air was necessary to maintain life, even the life of parasites on trees. He writes in 1700 of a free circulation of air as being necessary for insects which he had imprisoned in a glass tube for observation. In fact, he understood ventilation as few in his day did, except Stephen Hales, and had people understood it earlier there would have been less of gaol-fever and typhus fever everywhere, and poisoning of people to death on board ship. Leeuwenhoek was also something of a physiologist for he speculated on the use of the lacteals, of the "slime of the guts," and made an experiment to determine the amount of aqueous vapor daily excreted from the skin. He weighed a glass vessel dry, and, inserting his hand into it and closing up the orifice by a handkerchief packed round the wrist, he found moisture condensed on the inside of it. On weighing the vessel at once before the moisture evaporated, he obtained a distinct increase of weight, and by knowing the area of skin that had produced this, he arrived at the amount of sweat excreted per unit of surface-area. He then estimated the total area of the skin and found that the whole body per 24 hours must eliminate about 28 fluid ounces, which is not very far from the truth.

Leeuwenhoek was evidently possessed of sound commonsense. He could not bring himself to believe that the blood underwent any kind of a "fermentation" analogous to that of beer or wine as was at the time almost universally taught in the medical schools. He said very sensibly that he had never been able to see any bubbles of gas in the blood-vessels such as ought to have been there had the blood been the seat of fermentation as he understood it. However necessary this fermentation of blood was to the theoretical physiology of his day, that Leeuwenhoek could find no evidence of it was a serious objection seeing that he was one of the very few who was in the habit of looking at the living blood. Thus, although not a physician, and not even a professional man of science, he was considerably ahead of the physiology of his day in respect of some of its most important principles.

Leeuwenhoek is not forgotten in his own country, for the Royal Society of Amsterdam gives a medal once in ten years in recognition of the most important work done on microscopic organisms during the previous decade. In 1915 this medal was awarded to Major-General Sir David Bruce, Director of the Royal Society's commission for the investigation of the sleeping sickness.

As a lover of pure science, as a most industrious worker with the microscope, and as a prescient physiologist Leeuwenhoek is interesting to all those who study living nature, but by histologists and bacteriologists in particular his name will ever be regarded with that reverence which a bright example in science must always inspire. The man who first saw and described a micro-organism cannot fail to be interesting to us today seeing of what importance the microscope and its dependent science of bacteriology have become in modern life with their relations to applied medicine, pathology, surgery, public health, the arts, and commerce. The seed of this gigantic tree with its roots in all lands and its flowers culled under every clime was sown by the hand of a solitary worker without reward in a quiet little town on one of the canals of the great plain of Holland.